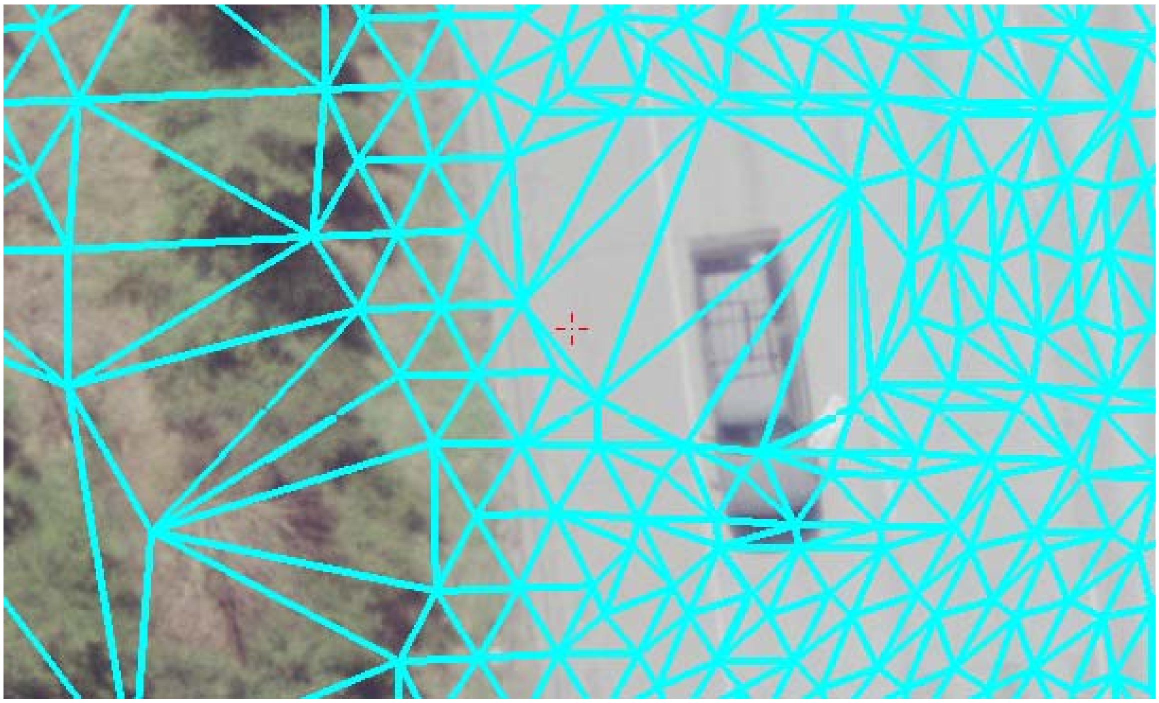
# A Practical Look At Comparing Puget Sound LIDAR Consortium (PSLC) Data to Field Survey Points Within A Photogrammetric Soft Copy Stereo Model.



*PSLC LIDAR digital Terrain Model (DTM) draped over WSDOT 1:3000 photo scale aerial photography in a 3.D. Photogrammetric Soft Copy System.*

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# Introduction

The need for efficient methods of providing elevation terrain models for mapping large areas has multiplied with the increased use of the digital ortho photo. Terrain model data can be collected by classical survey methods, photogrammetric techniques, or by emerging remote sensing technologies, such as Light Detection and Ranging (LIDAR).

LIDAR is a declassified military technology that relies on precise timing and recording of light pulse and detection of pulse reflection. LIDAR systems combine three maturing technologies:

(1) Light pulse scanner
(2) Inertial measurement system (IMU)
(3) Global Positioning System (GPS).

Installation of these systems in an airborne platform, such as an airplane or helicopter, allows LIDAR to collect millions of elevation points per hour. Advancements in LIDAR technologies, such as multiple return capabilities, have resulted in riparian and forestry analysis, among many other applications.

While traditional mapping methods are labor-intensive and costly, LIDAR appears to be a practical cost-effective and capable form of delivering useful data for determining floodplains, hydrology, over story and under story vegetation canopy, and other uses of landscape characteristic definition.

The object of this report is to examine bare-earth horizontal and vertical accuracy of LIDAR in various relief and vegetation conditions. The process selection will help validate the sensor, IMU, GPS and LIDAR data processing and analysis with respect to datum orientation.

# The Project Test Site

The project test site was selected for the following existing conditions:

(1) Availability of LIDAR
(2) Availability of dense geodetic and photogrammetric survey control
(3) Availability of photogrammetric mapping for highway design engineering
(4) Availability of landscape conditions that include relief in topography, various tree canopy and vegetation, residential, transportation corridor and riparian environments.

A 3000ft x 3500ft region was selected along the I405 corridor, north of the I 90 interchange. The area contained an excellent mix of Pacific Northwest topography and planimetry, including flat and steep terrain, high brush and trees, a major freeway, residential housing with open ground, plus a park and trail system through a marshland.

WSDOT Geographic Services large scale, high accuracy photogrammetric design mapping data (seen below), and specific field survey data was used to validate the LIDAR data.

# Methods Used To Validate LIDAR Performance

**GPS Field Data Collection**
Individual topographic ground positional data were collected utilizing GPS Real time Kinematic (RTK) techniques under ideal satellite conditions. Specifications included a calibration effort utilizing 5 existing survey control points with NSDI horizontal uncertainty of <1cm and vertical of <2cm. The RTK survey tolerance is <5cm, both horizontal and vertical. Re-initialization and redundant check measurements, using two antenna heights, were <2cm with RMS values <21.

**Photogrammetry Information**
An existing WSDOT large-scale high accuracy photogrammetric design project covered the test area with 1:3000 (1"=250') photo scale, color scanned (12.5 micron resolution) photography utilizing 5cm accurate field controlled targets. A.T. results signaled photogrammetric measurements of 2-3 tenths of a foot were achieved for well defined visible detail points on the imagery.

**LIDAR Data Information**
A bare-earth/cleaned (returns from trees and buildings eliminated) ASCII dtm-xyz point file supplied by the Puget Sound LIDAR Consortium (PSLC), via 1/25$^{th}$ quarter quad sized files. The PSLC data was trimmed to fit the desired area, without thinning of the data, and imported into a softcopy CAD photogrammetric environment for analysis. The trimmed data set contained 152,790 points!

Information available at Puget Sound LIDAR Consortium Home notes LIDAR data is accurate to 15cm (.49 of a foot). The PSLC delivers a disclaimer with the data, which states: "*We have taken considerable care to ensure that these topographic survey data and derived images are as accurate as possible. We believe most of these data are adequate for determination of flood hazards, for geologic mapping, for hydrologic modeling, for determination of slope angles, for modeling of radio wave transmissions, and similar uses with a level of detail appropriate to a horizontal scale of 1:12000 (1 inch = 1000ft) or smaller and a vertical accuracy on the order of a foot. Locally, the data are of considerably poor quality. Users should carefully determine the place-to-place accuracy and fitness of these data for their particular purposes. For many purposes a site-and use-specific field survey will be necessary.*"

*Bare ground PSLC xyz LIDAR data draped within a stereo model (two overlapping stereo photos 9"x9") in a soft copy 3.D. mapping system*

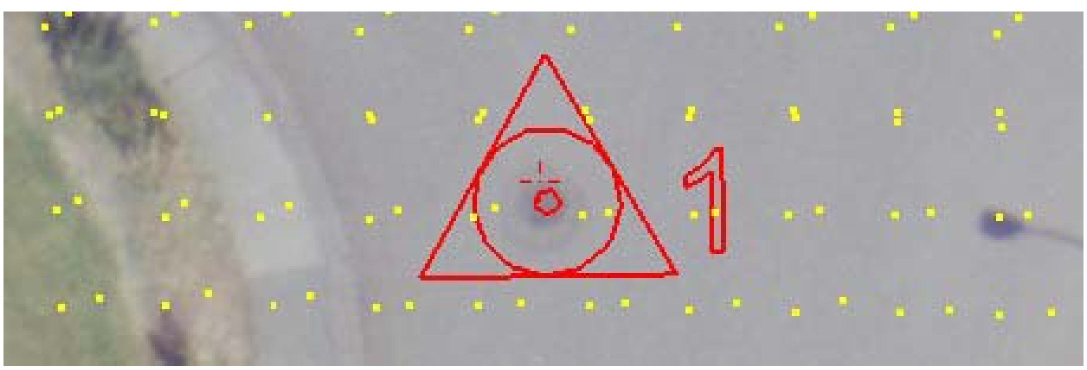
**Vertical Accuracy Validated**

The survey field data and the photogrammetrically controlled stereo model was used to validate the LIDAR data in the study area. The closest LIDAR xyz point to the field collected survey point was compared and vertical differences noted below. If several LIDAR pulses were close to the survey point with varying elevations, then both vertical differences were recorded. The 3.D. stereo model with color photography was also used to give an overall photogrammetric interpretation of the draped LIDAR data over the terrain throughout the study area.

# GPS Field Data Analysis

Terrestrial photos below reflect the landscape and surface environment where GPS field data was collected. Ortho photos below locate the survey point with a red triangle. The yellow dots surrounding the survey point mark the location of each LIDAR pulse position. The nearest LIDAR pulse positions were compared to the GPS field data and differences listed below ortho photo.

*QC1*-Manhole cover in paved street at intersection of SE 20th/121 Ave. SE.

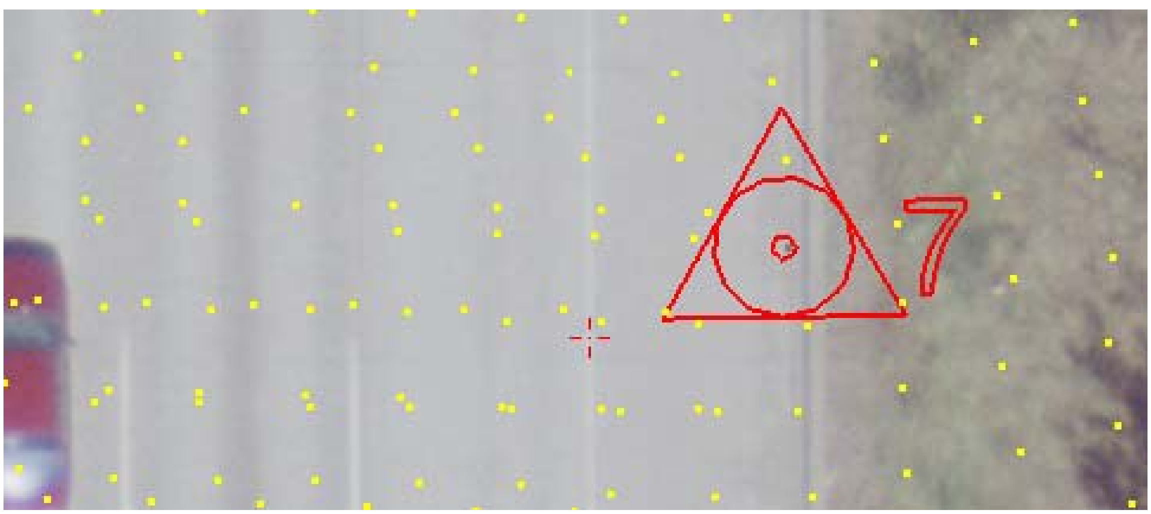



LIDAR vertical differences: +0.22ft.
LIDAR horizontal point proximity to survey point: 1.76ft.

*QC6*-East side of SR405, halfway up the hillside in knee-high grass, surrounded by brush and trees.

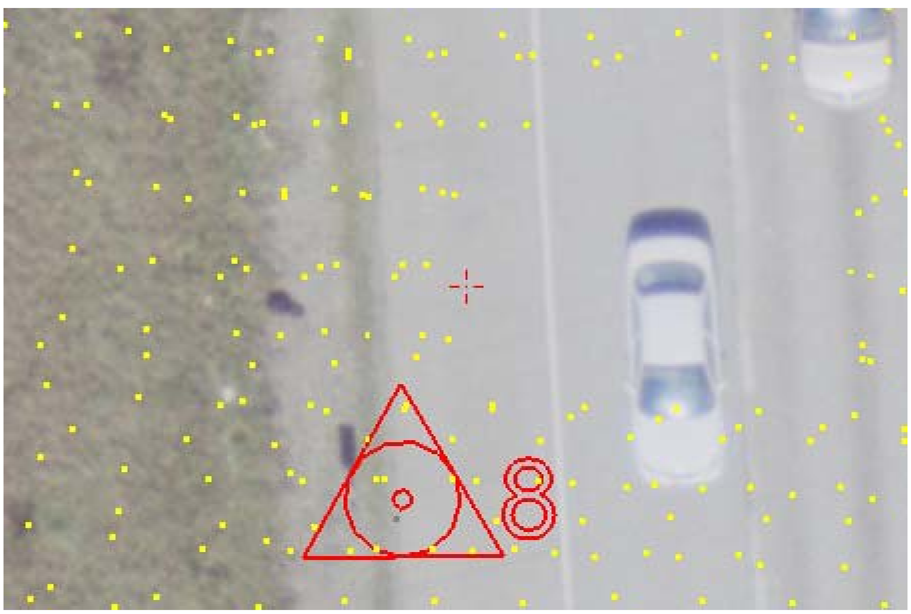

LIDAR vertical differences: +0.97ft.
LIDAR horizontal point proximity to survey point: 2.2ft.

*QC7*-East side of SR405 on the pavement near a retaining wall. Transportation corridor landscape. Trees and obstructions to the east.




LIDAR vertical differences: +0.30ft.
LIDAR horizontal point proximity to survey point: 0.27ft.

*QC8*-West side of SR405, southbound lanes, on the edge of pavement at MP12. Transportation corridor landscape. No obstructions.




LIDAR vertical differences: +0.31ft.
LIDAR horizontal point proximity to survey point: 1.3ft.

*QC9*-West side of SR405, southbound lanes, near the top of slope, in 12" high grass at the westerly tree line.  Transportation corridor landscape.


LIDAR vertical differences: -0.51ft.
LIDAR horizontal point proximity to survey point: 2.1ft.

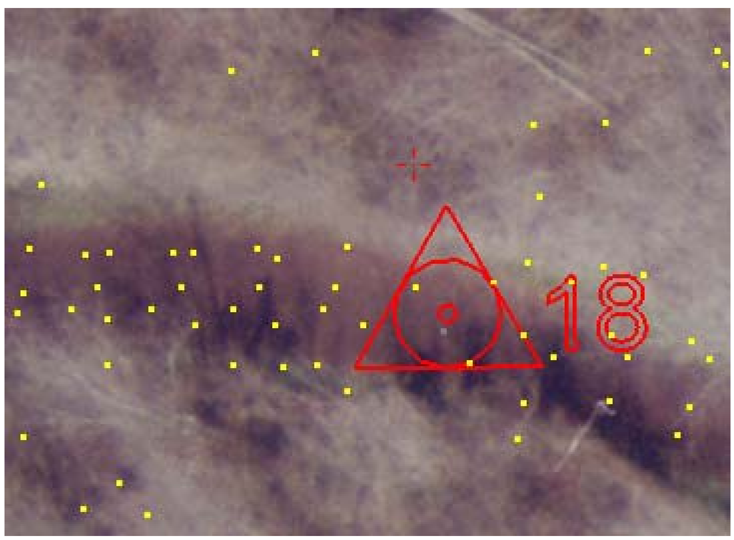
*QC11*-East edge of city street, in a gravel pull out. Embankment and tall fence in an easterly direction.  Residential transportation landscape.


LIDAR vertical differences: +0.07ft. & +0.34ft.
LIDAR horizontal point proximity to survey point: 2.5ft. & 1.86ft.

*QC17*-Ground surface of wood chip trail, entirely surrounded by tall trees. Very obstructed.  Marshland riparian landscape.


LIDAR vertical differences: +0.34ft. & -0.12ft.
LIDAR horizontal point proximity to survey point: .09ft. & .09ft.

*QC18*-Ground surface of wood chip trail, surrounded by tall trees.  Obstructed. Marshland riparian landscape.




LIDAR vertical differences: +0.45ft. & +1.79ft.
LIDAR horizontal point proximity to survey point: 1.18ft. & 8.1ft.

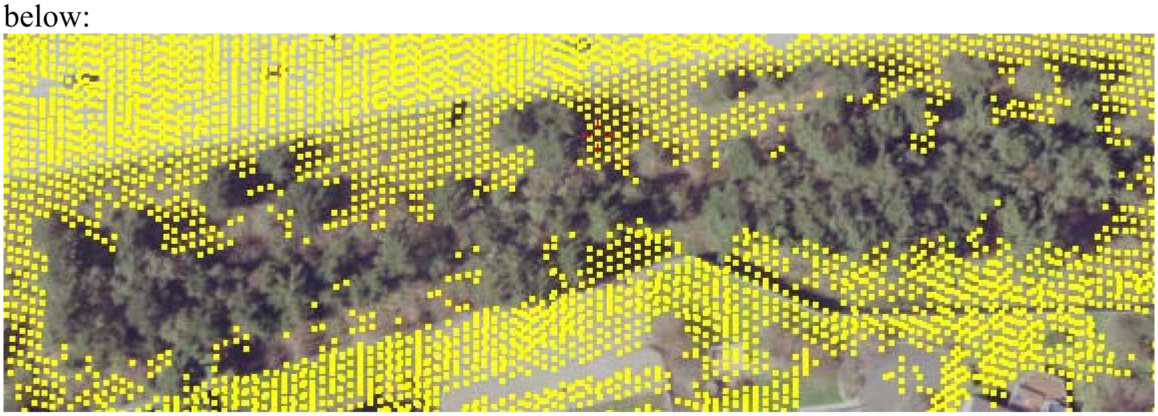
**Results of GPS Field Data Analysis**
The small vertical sampling of 8 survey points cuts a profile through the study area in an east to west direction.  Although results are not conclusive for the entire area, a

comparison between survey field data and LIDAR demonstrates a maximum vertical difference of 1.79ft and minimum vertical difference of 0.07ft. The differences represent displacement between survey field control and nearest LIDAR points as measured within a 3.D. photogrammetric stereo model. Results show the data could be utilized for 1-2 foot or greater vertical mapping accuracy specifications (as stated by PSLC) in this study area. With some photogrammetric editing (adding data to better depict changes in grade) or cleaning, this data could be used to provide accurate elevation data for 1:12,000 scale or smaller orthophotography. It is not accurate enough for large-scale WSDOT engineering design level mapping accuracy specifications, where <3 tenths of a foot vertical accuracy is desired. This test verifies the PSLC statement: "*locally, the data are of considerably poorer quality*" Due to this fact WSDOT large scale design projects should not utilize LIDAR data. It is a tool best used for regional research and planning purposes or geological fault analysis, forest characterization, and flood plain modeling. WSDOT might best utilize LIDAR data for remote areas and applications where vertical accuracies of less than a foot are not needed.

# Photogrammetric Mapping Analysis

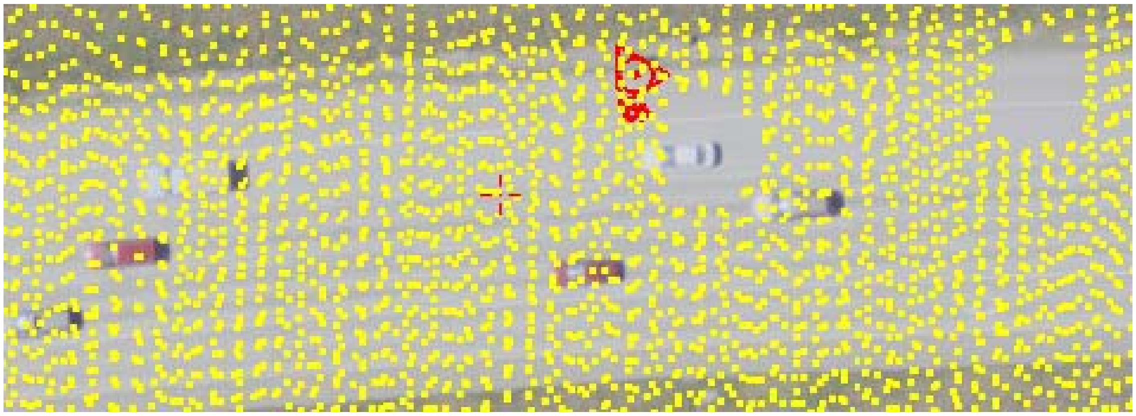
The LIDAR data was draped onto a single stereo model and interpretive evaluations of the entire study area was achieved in a 3.D. environment.

Heavy tree cover, with heights from 20 to 40+ feet prevented pulses from penetrating the ground. The PSLC data covering forested areas, of this type was devoid of data as seen below:



The PSLC data within the park trail area which included heavy brush and trees 6 to 20 feet had a good deal of erroneous data (in the region of +10feet), mostly pulse returns from the top of the brush and small trees.

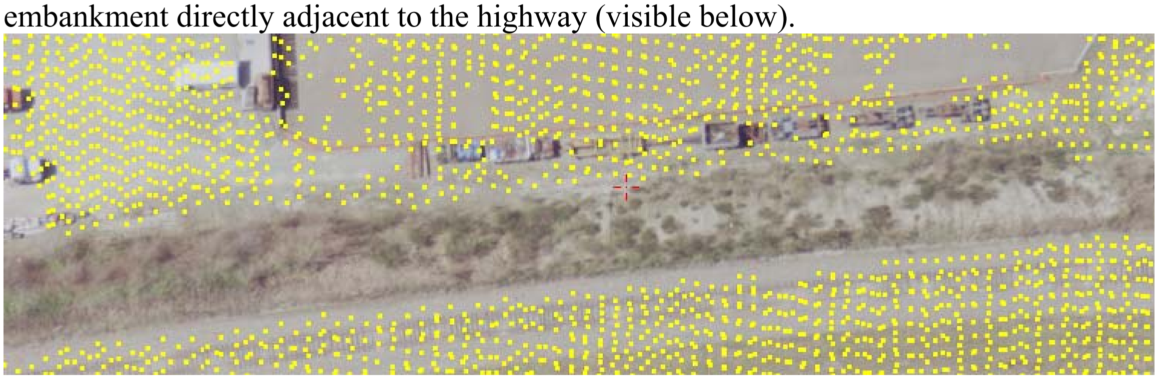
The PSLC data on the paved corridor surface appeared to be made up of two separate swaths with double the number of points compared to surrounding areas. One swath was on average .5ft above the road pavement, while the other swath better matched the 3.D. stereo models of the road surface. The shoulders, edges of ditches, bottoms/tops of retaining walls (changes in road grades) were often not well defined and the points generating tin triangles often floated or dug into the 3.D. terrain.



Example of freeway data with void areas, possibly from pulse returns from vehicles.

The PSLC data on bare ground steep slopes, without great change in grade, did a good job of depicting the ground surface.  It did not transition well next to trees and often stair-stepped erroneous data up into the air in areas adjacent to trees.  A large patch of brush within a bare ground region was sometimes miss-captured and the top of the brush identified as true ground.

The PSLC data appeared to have incorrectly stripped out an entire 5-foot high embankment directly adjacent to the highway (visible below).



Overall, the PSLC dataset was devoid of gross error over ten feet in vertical elevation.

# Considerations When Using LIDAR Data

LIDAR is best suited for providing data for areas normally beyond WSDOT transportation corridors, such as watershed studies. Also LIDAR is well suited for smaller scale (1:12000 photo scale or smaller) orthophotography projects. Photogrammetry stereo model analysis is an excellent way to validate the data and edit out erroneous returns and add data to better depict tops and bottoms of slopes, retaining walls, ditches, etc.  LIDAR does not model changes in grade well, but prefers consistent terrain where statistical algorithms work best for stripping erroneous pulse returns.

Users must be aware that LIDAR files ARE VERY LARGE and most often the data must be thinned (although this will reduce the accuracy of the data). This small study area included more than 152 thousand points! PC processing time and computing power must be evaluated. Most CAD systems will struggle with un-thinned data. Typically LIDAR data must be cut and thinned into smaller, more manageable units, to alleviate limitations in CAD file maximum point sizes.

Raw LIDAR data must forgo an editing process to strip out erroneous laser returns from tops of trees, cars, birds, buildings, tops of brush, etc. to provide a bare-ground final terrain deliverable. LIDAR software often calculates average elevation differences between first and last returns. Although commercial proprietary editing software is automated, not all errors are eliminated and field surveying or photogrammetric validation is highly recommended.

The landscape & topography of your project area should also be assessed before finalizing data collection options. Hopefully, this small but practical assessment has given the reader a better understanding of PSLC LIDAR data. LIDAR is a tool, like surveying or photogrammetry, the user must understand project requirements and determine the proper discipline for achieving a successful project.

This report was prepared by Kurt Iverson, PLS, Survey Manager, and practical assessment was undertaken by Jason Goldstein, Photogrammetrist 2, both from Geographic Services, WSDOT, 5-20-03. Contact Information:
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